

Systematics of Intertidal Sponges from California and Korea

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ABSTRACT

A taxonomic study on the marine sponges was conducted with materials collected from intertidal zone of Southern California (USA) during 2005-2006. They were identified into 13 species belonging to 12 genera, nine families, and seven orders in one class. Among them, common species in Korea and California coastal areas are; *Cliona celata*, *Lissodendoryx firma*, *Halichondria panicea*, *Hymeniacidon sinapium*.

Key words: taxonomy, sponges, intertidal, California

INTRODUCTION

A number of taxonomic studies have been done on marine Porifera from California. The first was by Haeckel (1872) who described three calcareous species. This was followed by Lambe (1894) who reported sponges from the western coast of North America, Schulze (1899) who described 14 species of sponges from California, and Lendenfeld (1910) who authored a large monograph on the family Geodidae. A major advance was that of de Laubenfels (1932) who authored a book titled "The Marine and Fresh-water Sponges of California" which described 50 species in 10 orders of sponges. This was followed by three editions of Light's Manual, beginning in 1941 (Light, 1941; Light et al., 1954; Smith and Carlton, 1975) and the last of which reported 60 species of marine sponges. Morris et al. (1980) discussed 24 species of marine sponges from California and Lee et al. (2007a) presented a key to 256 species of California marine Porifera. The 4th edition of Light's Manual includes a chapter on Porifera by Lee et al. (2007b). They discuss 80 species of sponges ranging from central California to Oregon. The present study is done an attempt to compare intertidal marine sponges from California with those of Korea. The specific sites were selected so that some comparisons could be made between sponge species richness in previous studies and that of the present study.

MATERIALS AND METHODS

The field surveys on marine Porifera was ranged from the

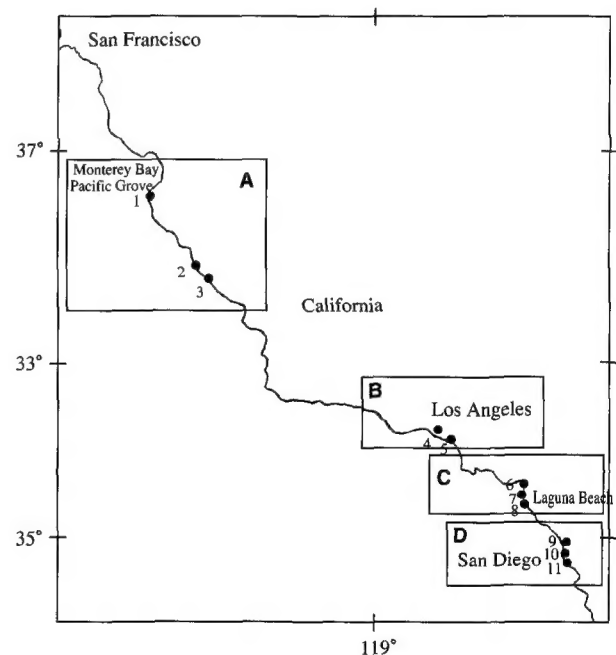


Fig. 1. Collecting area. A, Central coast area: 1, Pacific Grove (Monterey); 2, Cayucos; 3, San Simeon. B, Los Angeles County Area: 4, Paradise Cove, Malibu; 5, Palos Verdes Peninsula. C, Orange County Area: 6, Little Corona Del Mar; 7, New Port; 8, South End of Crescent Bay in Laguna Beach. D, San Diego County Area: 9, La Jolla Cove; 10, Bird Rock; 11, Pt. Loma.

central California Monterey Peninsula to San Diego (Fig. 1). The material examined was collected from 12 localities representing an overall high diversity. The specimens were deposited in the invertebrate collections of the Los Angeles County Museum of Natural History in Los Angeles, California. They were fixed in 95% or 99.9% ethanol. Spicules

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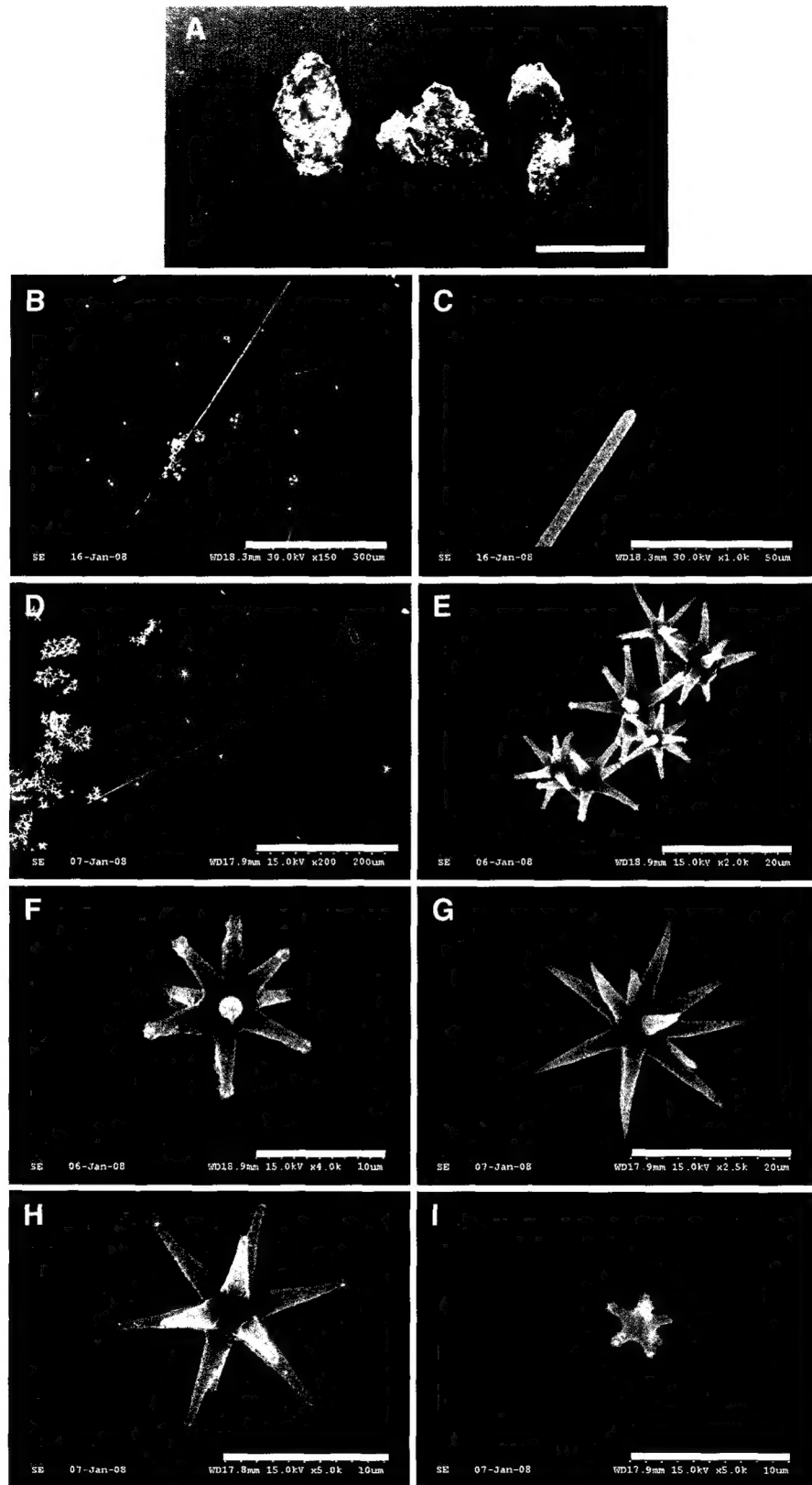


Fig. 2. *Timae authia*. A, entire animal; B, style; C, end of style; D, tylostyle; E-I, microscleres; aster. Scale bars=1 cm (A), 300 μ m (B), 50 μ m (C), 200 μ m (D), 20 μ m (E-G), 10 μ m (H, I).

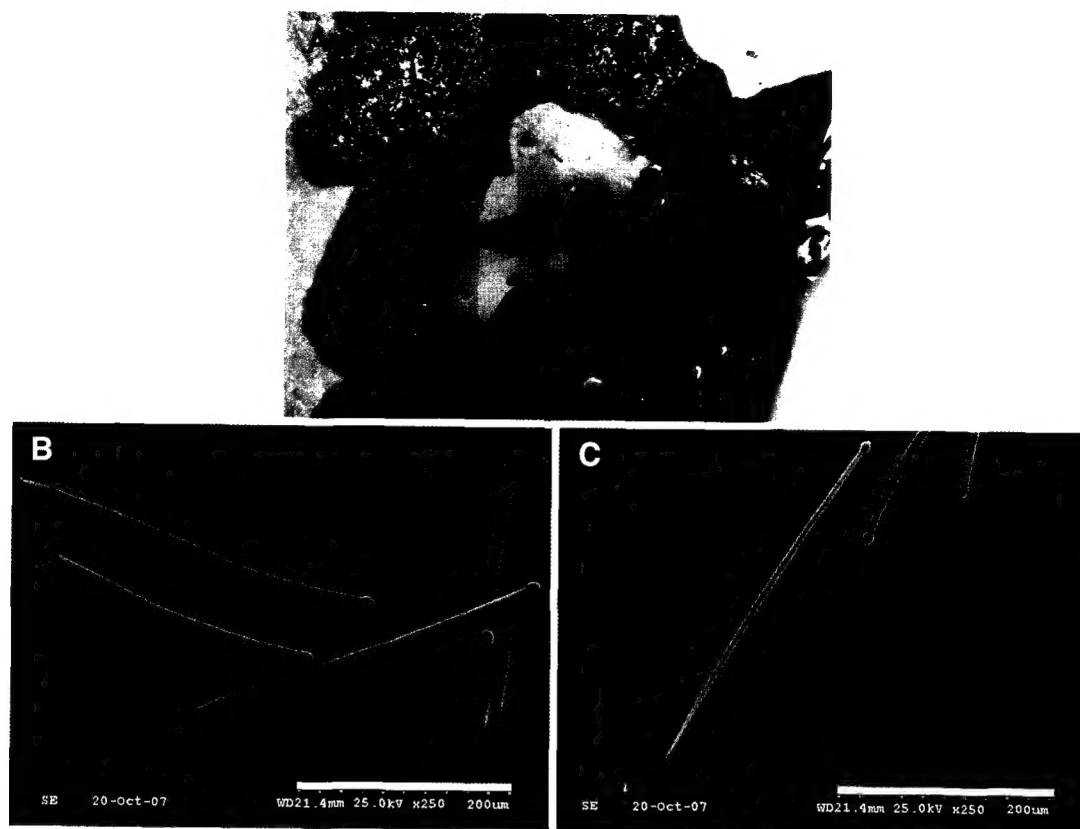


Fig. 3. *Cliona celata*. A, entire animal; B, thick tylostyle; C, slender tylostyle. Scale bars=200 μ m (B, C).

were observed by light microscopy (Carl Zeiss Axioskop II) and scanning electron microscopy (SEM, HITACHI S-3000N). Identifications were made on the basis of external features, shape, structure of the skeleton, and the size and the form of spicules. Thin freehand sections were made with specimens hardened in alcohol using a surgical blade in order to observe the structure of the skeleton. Spicules were prepared by dissolving a piece of the sponge in sodium hypochlorite and examined with SEM, following the methods of Rützler (1978) and Hooper (1996).

SYSTEMATIC ACCOUNTS

Phylum Porifera Grant, 1836
Class Demospongiae Sollas, 1885
Order Hadromerida Topsent, 1894
Family Timeidae Topsent, 1928

1. *Timea authia* de Laubenfels, 1930 (Fig. 2)

Timea authia de Laubenfels, 1930, p. 26.

Timea authia: de Laubenfels, 1932, p. 45, fig. 21.

Material examined. La Jolla Cove, 1 Dec. 2005.

Description. Encrusting shape, size up to 1.3×0.7 and 0.1 cm thick. Texture, soft and fragile. Colour, white in alcohol. Oscules, not conspicuous. Megascleres, style. Microscleres, aster.

Megascleres

Style $370-720 \times 2.5-7.5 \mu\text{m}$

Microscleres

Aster $10-20 \mu\text{m}$

Remark. This species is slightly different from the specimen of de Laubenfels (1930) in the shape of the tylasters which has numerous spines at the end of the rays, but the overall structure of the spicules are similar to each other. It is distributed in the intertidal zone of Southern California but is not found in South Korea.

Distribution. Southern California.

Order Hadromerida Topsent, 1894

Family Clionaidae D'Orbigny, 1851

2. *Cliona celata* Grant, 1826 (Fig. 3)

Previous records. Rho et al., 1969; Rho and Sim, 1972; Rho and Lee, 1976; Sim and Shim, 2006.

Material examined. South End of Crescent Bay, 1 Mar.

2006; Cayucos, 24 Mar. 2006.

Description. Massive shape, size up to $4.5 \times 2.5 \times 1.5$ cm. Texture, rough and firm. Colour, brown in alcohol. Oscules, not conspicuous. Spicules, tylostyle.

Spicule.

Tylostyle $210\text{--}370 \times 5\text{--}13 \mu\text{m}$

Remark. The specimen from Korea seems to be close to the species from Southern California based on the structure of the spicule. However, the species from Korea displays larger tylostyle (Table 1).

Distribution. Korea, Japan, Southern California, North Atlantic Ocean, Mediterranean, Australia.

Table 1. Comparison between characters of *Cliona celata* from Southern California and Korea

Character Locality	Shape	Color	Texture	Tylostyle (μm)
Cayucos (Southern California)	Massive	Brown	Firm	$210\text{--}370 \times 5\text{--}13$
Chujado Island (Korea)	Massive	Brown	Firm	$240\text{--}410 \times 7\text{--}15$

Order Poecilosclerida Topsent, 1928

Suborder Microcionina Hadju, Van Soest and Hooper, 1994

Family Microcinidae Cater, 1875

Subfamily Microcioninae Cater, 1875

3. *Clathria (Microcionia) pennata californiana* de Laubenfels, 1932 (Fig. 4)

Ophlitaspongia pennata californiana de Laubenfels, 1932, p. 104.

Material examined. Pacific Grove, 28 Jan. 2006; San Simeon, 25 Mar. 2006.

Description. Encrusting shape. Size up to $4.2 \times 2.8 \times 0.3$ cm. Texture, rough and firm. Colour, Orange in life which gradually changes to ivory. Oscules, not conspicuous. spicules, magascleres, two size of subtylostyle. Microscleres, toxa.

Megascleres

Thick subtylostyle $130\text{--}330 \times 9\text{--}16 \mu\text{m}$

Thin subtylostyle $105\text{--}160 \times 2\text{--}4 \mu\text{m}$

Microscleres

Toxa $40\text{--}95 \mu\text{m}$

Distribution. Southern California.

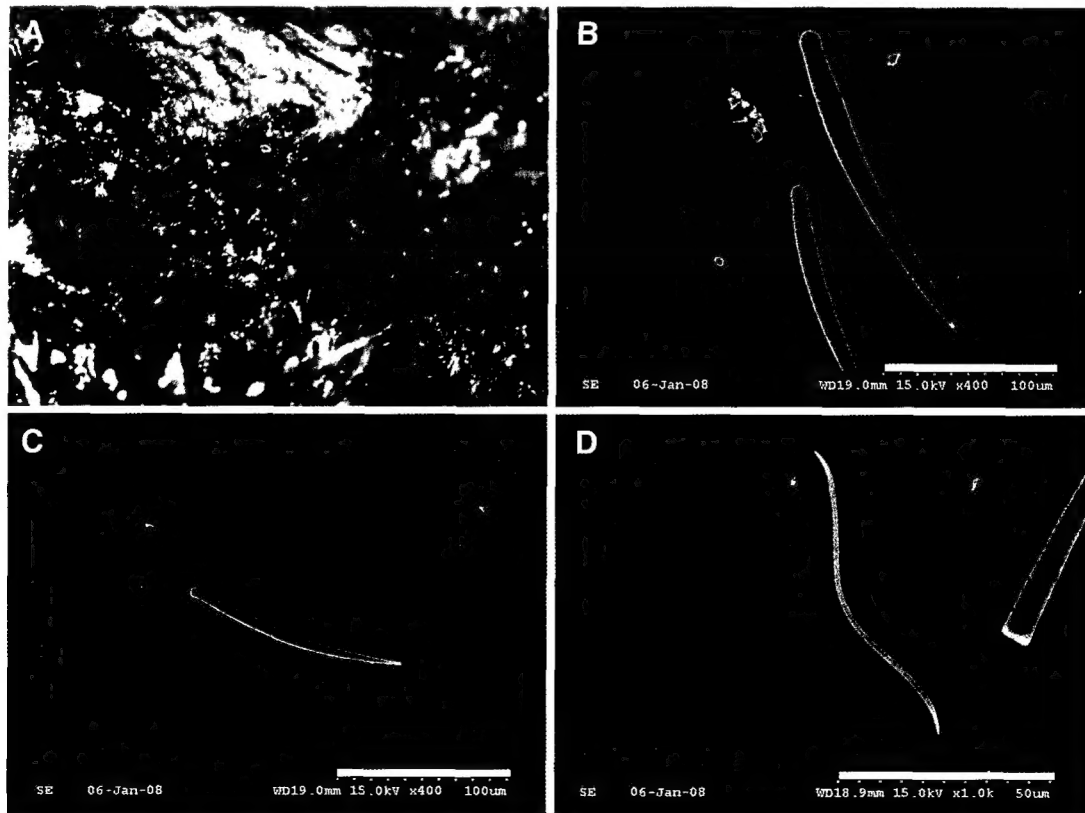


Fig. 4. *Clathria (Microcionia) pennata californiana*. A, entire animal; B, large style; C, small style; D, toxa. Scale bars=100 μm (B, C), 50 μm (D).

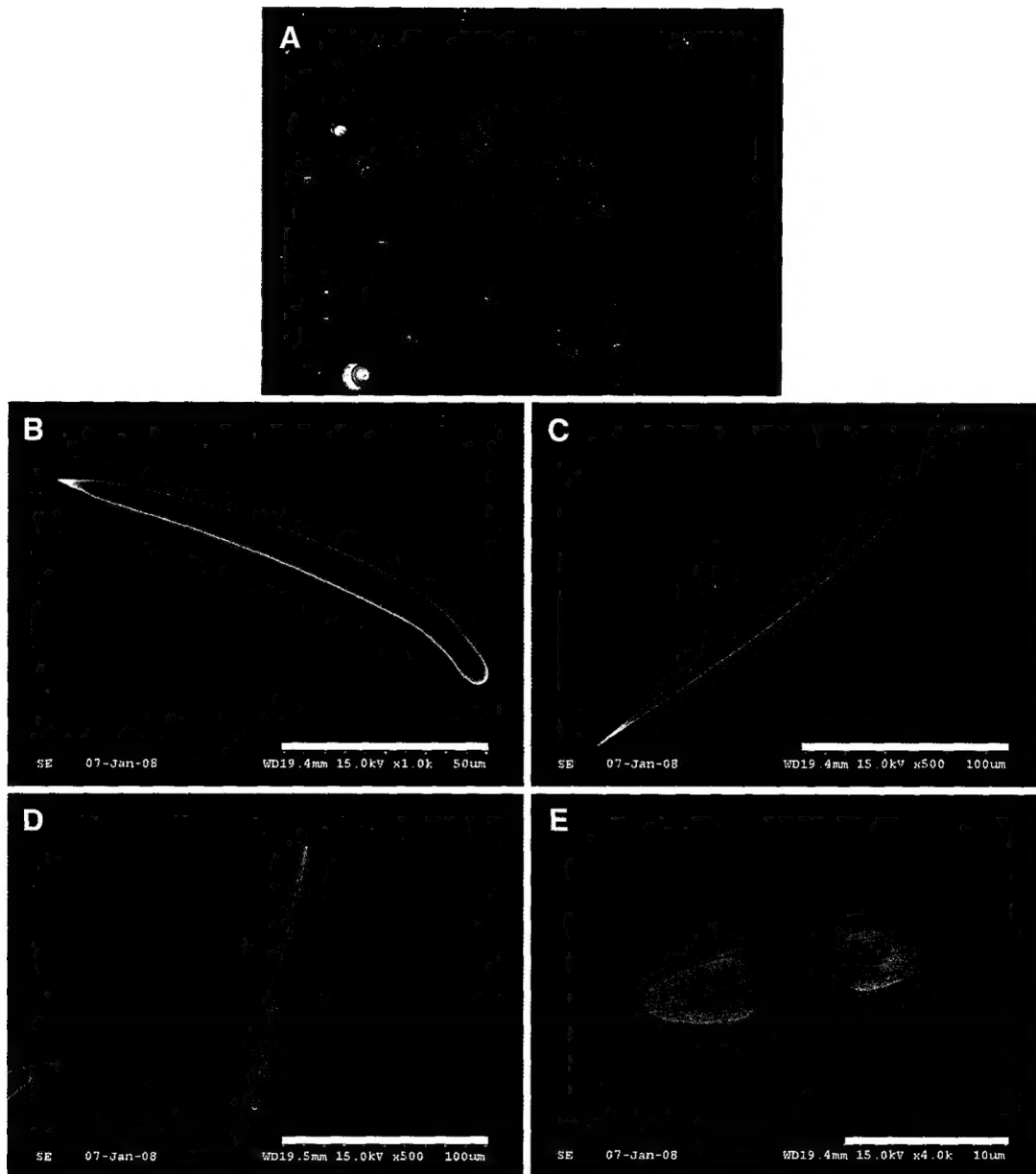


Fig. 5. *Clathria (Thalysias) originalis*. A, entire animal; B, thick style; C, slender style; D, small style; E, isochela. Scale bars=50 µm (B), 100 µm (C, D), 10 µm (E).

4. *Clathria (Thalysias) originalis* De Laubenfels, 1930 (Fig. 5)

Material examined. San Simeon, 25 Mar. 2006.

Description. Thin encrusting, size up to 1.5 × 1 and 0.1 cm thick. Texture, soft and fragile. Colour, red in life which gradually changes to ivory. Oscules, 0.1 cm scattered on the surface. Spicules, megascleres, two size of style. Microscleres, isochela.

Megascleres

Thick style 120-330 × 10-15 µm
Thin style 120-250 × 3-5 µm
Microscleres
Isochela 15-20 µm

Distribution. Southern California.

Subfamily Ophlitasponiinae De Laubenfels, 1936

5. *Antho (Antho) lithophoenix* de Laubenfels, 1927 (Fig. 6)

Plocamia lithophoensix de Laubenfels, 1927. p. 263.

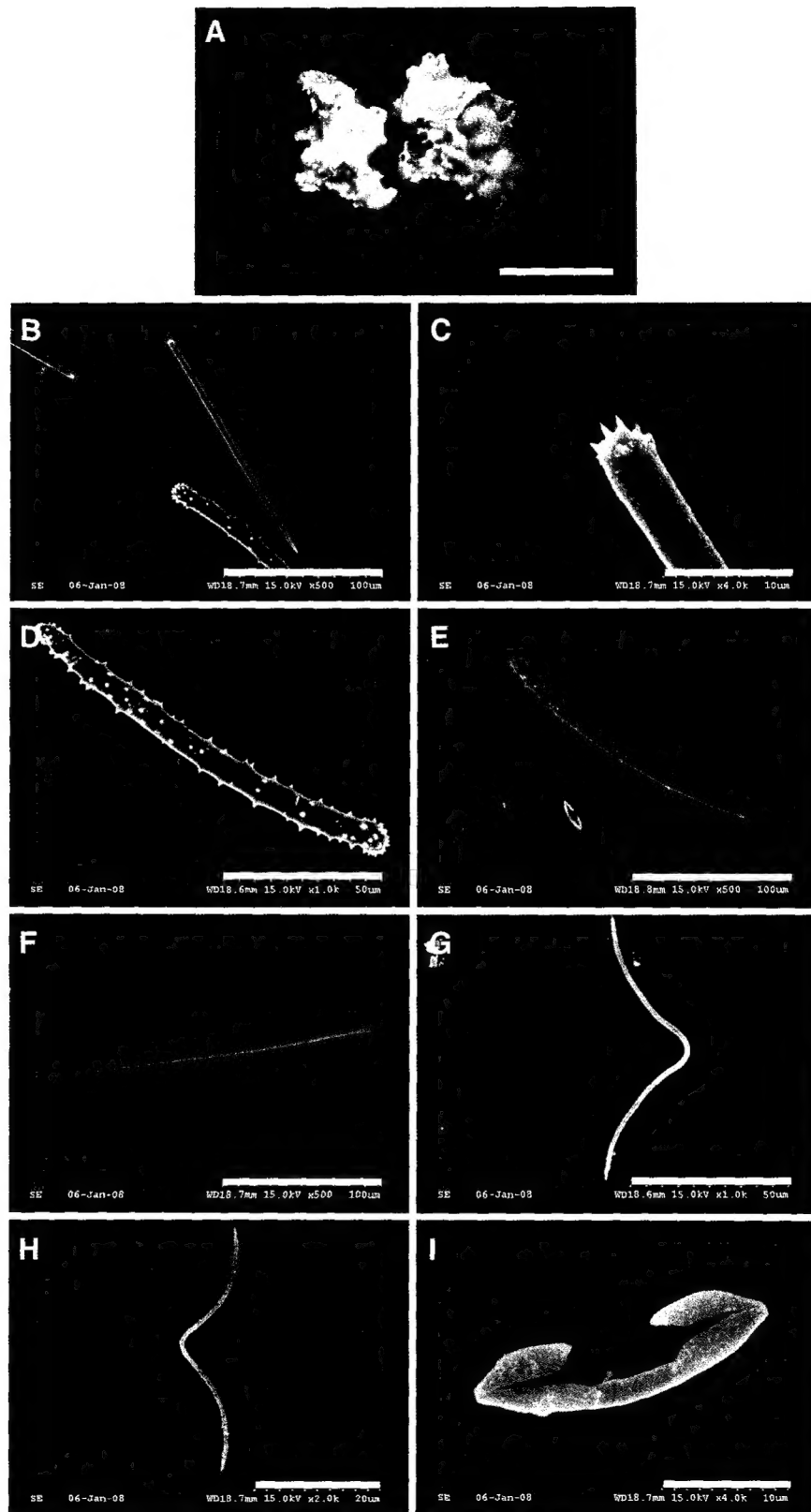


Fig. 6. *Antho (Antho) lithophoenix*. A, entire animal; B, thick style; C, head of style; D, acanthostrongyle; E, Acanthostyle; F, slender style; G, large toxa; H, small toxa; I, isochela. Scale bars=1 cm (A), 100 μ m (B, E, F), 50 μ m (D, G), 20 μ m (H), 10 μ m (C, I).

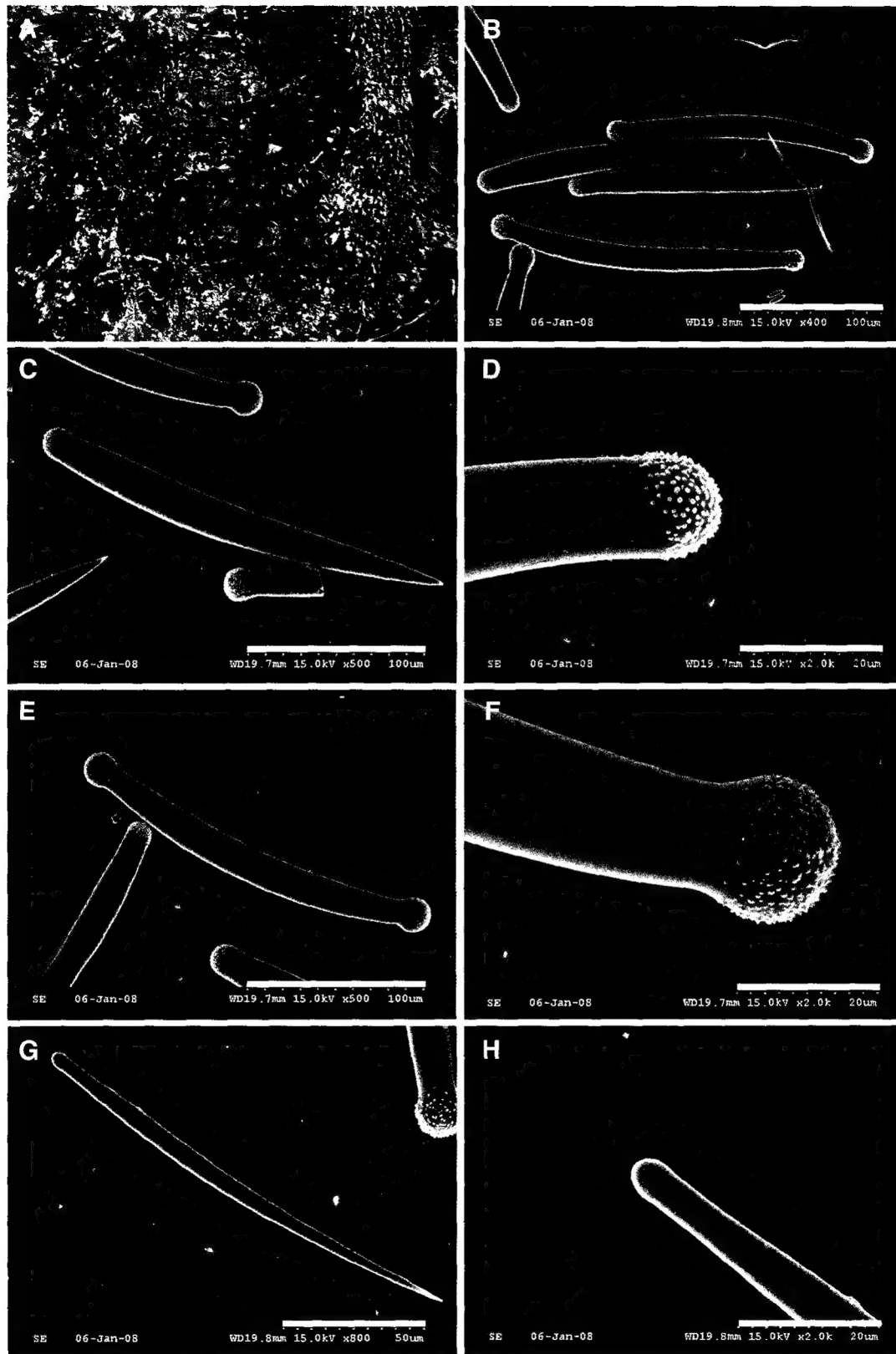


Fig. 7. *Antho (Acarina) karykina*. A, entire animal; B, spicule; C, thick style; D, head of thick style (acantho); E, strongyle; F, head of strongyle (acantho); G, slender style; H, head of slender style. Scale bars=100 μ m (B, C, E), 50 μ m (G), 20 μ m (D, F, H).

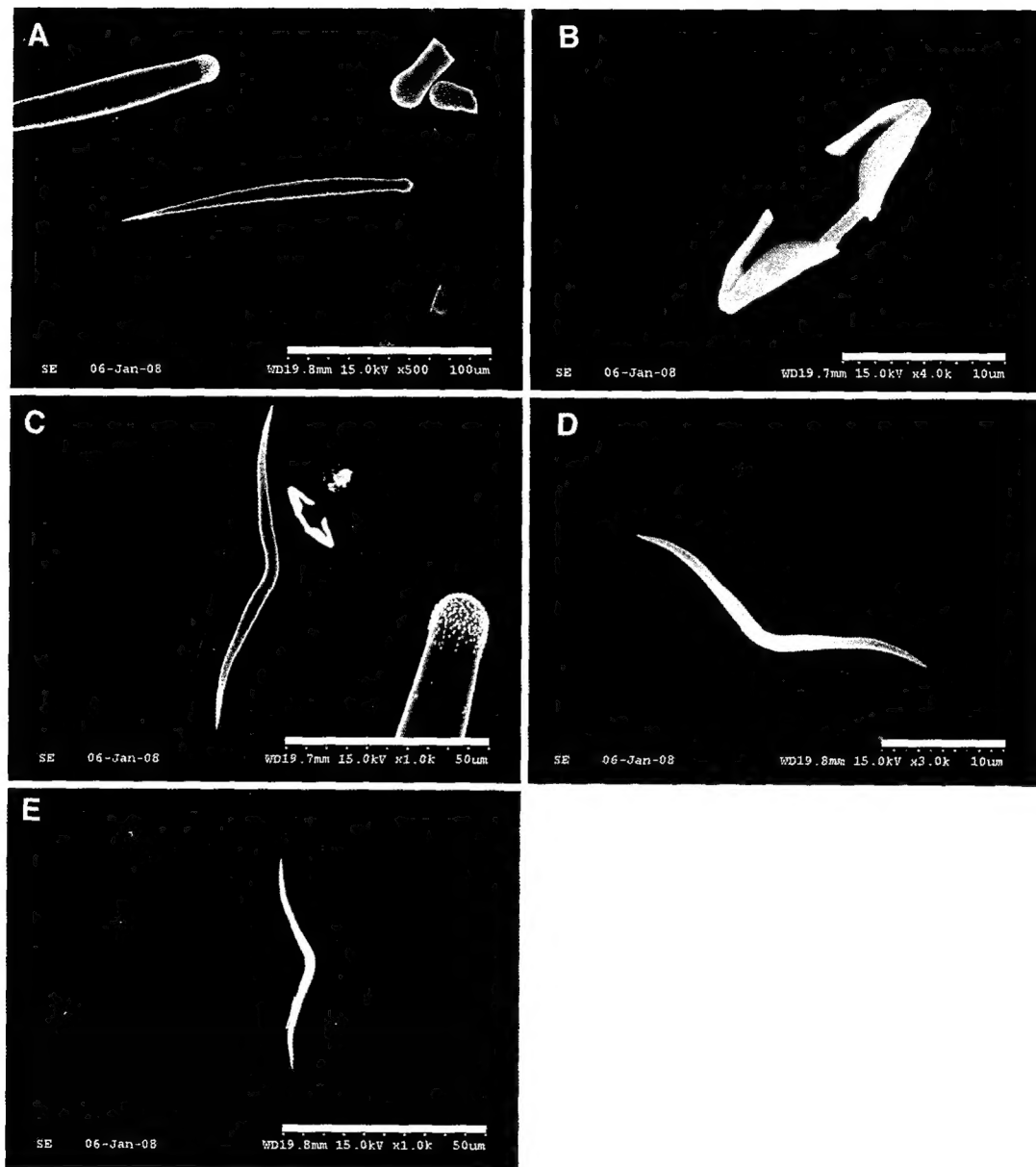


Fig. 8. *Antho (Acarina) karykina*. A, small style; B, isochela; C, large toxa; D, middle toxa; E, small toxa. Scale bars=100 μ m (A), 10 μ m (B, D), 50 μ m (C, E).

Isociona lithophoensix de Laubenfels, 1930, pp. 99-100, fig. 50.

Material examined. Pacific Grove, 28 Jan. 2006.

Description. Thinly encrusting, size up to 1.5×1.3 and 0.4 cm thick. Texture, soft. Colour, orange in life which gradually changes to ivory. Oscules, inconspicuous. Spicules, megascleres, style, subtylote and acanthostrongyle. Microscleres, isochela and three sizes of toxa.

Megascleres

Style	180-300 \times 10 μ m
Subtylote	190-290 \times 5 μ m
Acanthostrongyle	120-140 \times 7.5-10 μ m
Microscleres	
Large toxa	180-190 μ m
Middle toxa	95-120 μ m
Small toxa	32.5-55 μ m
Isochela	17.5-24 μ m

Remark. It is distributed in the intertidal zone of Southern California but is not found in South Korea.

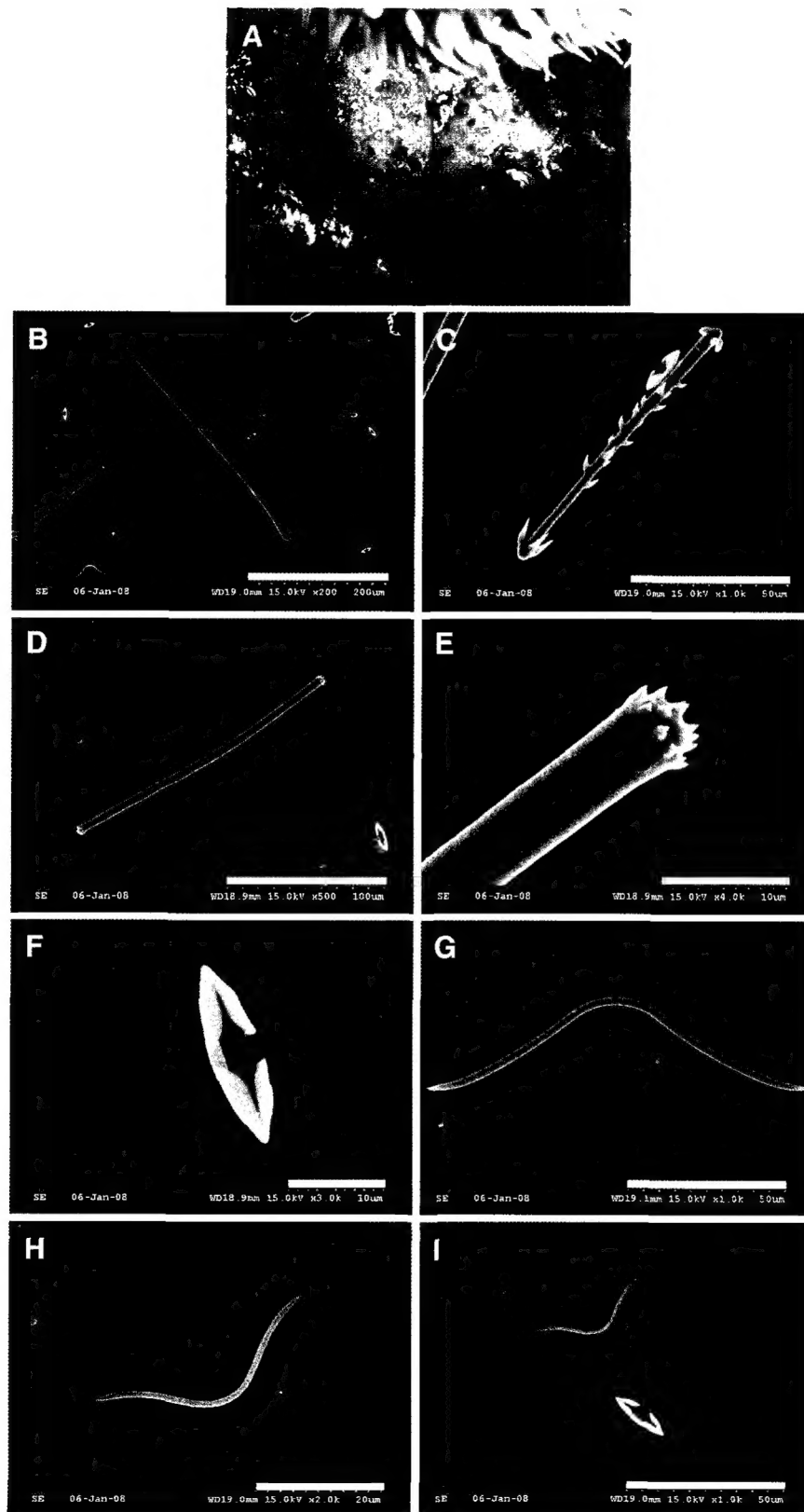


Fig. 9. *Acarnus erithacus*. A, entire animal; B, style; C, clad tylote; D, strongyle; E, head of strongyle (acantho); F, isochela; G, large toxa; H, middle toxa; I, small toxa and isochela. Scale bars=200 μ m (B), 100 μ m (D), 50 μ m (C, G, H), 20 μ m (I), 10 μ m (E, F).

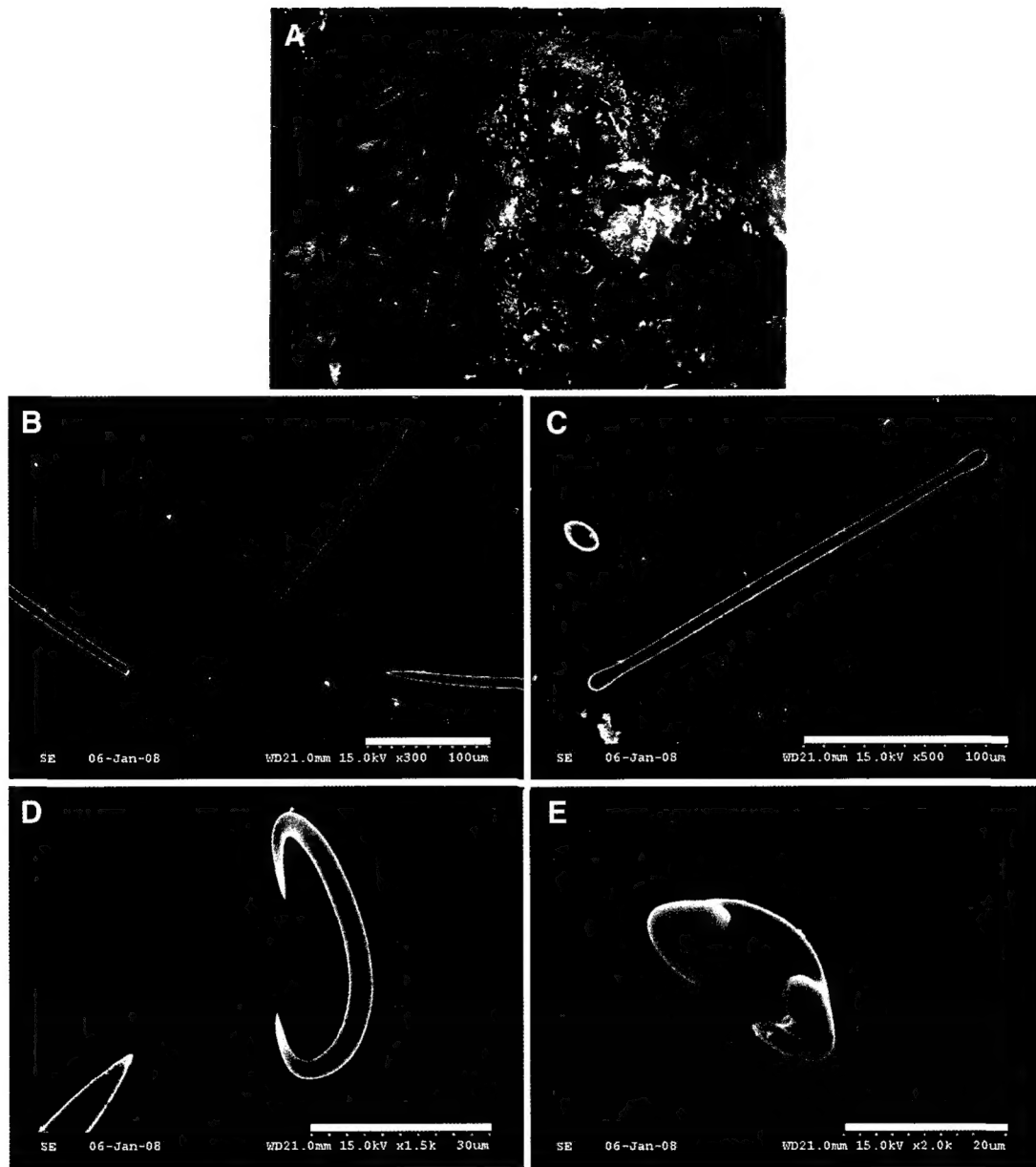


Fig. 10. *Lissodendoryx firma*. A, entire animal; B, style; C, tylote; D, sigma; E, isochela. Scale bars=100 µm (B, C), 30 µm (D), 20 µm (E).

Distribution. Southern California.

6. *Antho (Acarinia) karykina* de Laubenfels, 1927 (Figs. 7, 8)

Plocamia karykinos de Laubenfels, 1927, p. 262, figs. 1-6.

Plocamia karykina de Laubenfels, 1930, p. 28.

Material examined. Pacific Grove, 28 Jan. 2006; Palos Verdes Peninsula, 12 Oct. 2005; 13 Feb. 2006; Little Corona Del Mar, 14 Feb. 2006; South End of Crescent Bay, 1 Mar.

2006.

Description. Thick, rounded shape, size up to 1.9×1.6 and 0.7 cm thick. Texture, tough and hard. Colour, red and brown in life which gradually changes to brown. Oscules, conspicuous. Spicules, megascleres, two sizes of style, tylote. Microscleres, isochela and three sizes of toxa.

Megascleres

Thick style	190-250 \times 15-20 µm
Thin style	115-190 \times 3-4 µm
Tylote	175-225 \times 15-24 µm

Table 2. Comparison between characters of *Lissodendoryx firma* from Southern California and Korea

Locality	Character	Shape	Color	Texture	Spicule (μm)			
					Style	Subtylote	Isochlea	Sigma
San Simeon (Southern California)		Massive	Yellow	Tough and compressible	235-270 \times 8-10	230-255 \times 4-8	25-27	35-60
JeJudo Island (Korea)		Massive	Yellow	Tough and compressible	290-320 \times 8-10	250-290 \times 4-5	25-30	35-50

Table 3. Comparison between characters of *Hymeniacidon sinapium* from Southern California and Korea

Locality	Character	Shape	Color	Texture	Spicule (μm)	
					Large style	Small style
Cayucos (Southern California)		Encrusting	Yellow	Soft	230-305 \times 7-11	130-150 \times 3-7
Paradise cave (Southern California)		Massive	Yellow	Soft	245-320 \times 5-8	110-140 \times 4-5
Chujado Island (Korea)		Encrusting	Orange	Soft	220-320 \times 5-10	180-220 \times 2-3

Microscleres

Large toxa 80-100 μm Middle toxa 30-55 μm Small toxa 15-20 μm

Distribution. Southern California.

Family Acarnidae Dendy, 1922

7. *Acarnus erithacus* de Laubenfels, 1927 (Fig. 9)*Acarnus erithacus* de Laubenfels, 1927, p. 258.*Acarnus erithacus*: de Laubenfels, 1930, pp. 104-107, fig. 63.

Material examined. Pacific Grove, 28 Jan. 2006.

Description. Massive shape. Size up to 2.2 \times 1.5 \times 1.5 cm. Texture, rough and firm. Colour, yellow in life which gradually changes to ivory. Oscules, 0.1-0.2 cm. Magascleres, style, strongyle, two sizes of cladotylote. Microscleres, three sizes of toxa and isochela.

Magascleres

Style 340-420 \times 11-17 μm Strongyle 175-310 \times 5-9 μm Thick Cladotylote 180-190 \times 8-9 μm Thin Cladotylote 95-100 \times 3-4 μm

Microscleres

Large toxa 250-320 μm Middle toxa 80-155 μm Small toxa 35-40 μm Isochela 15-20 μm

Distribution. Southern California.

Suborder Myxillina Hajdu, Van Soest and Hooper, 1994

Family Coelosphaeridae Dendy, 1922

8. *Lissodendoryx firma* Lambe, 1895 (Fig. 10)

Previous records. Sim, 1981; Sim and Kim, 2002; Sim and Kang, 2004; Sim and Shim, 2006.

Material examined. San Simeon, 25 Mar. 2006.

Description. Massive, size up to 2.5 \times 1.4 and 1 cm thick. Texture, tough and compressible. Colour, yellow in life which gradually changes to ivory. Oscules, inconspicuous. Spicules, megascleres, style and subtylote. Microscleres, sigma and isochela.

Megascleres

Style 235-270 \times 8-10 μm Subtylote 230-255 4-8 μm

Microscleres

Sigma 35-60 μm Isochela 25-27 μm

Remark. This species from Korea seems to be close to the species from Southern California based on the structure of the spicules. However, the species from Korea displays larger style and subtylote sizes (Table 2).

Distribution. Korea, Southern California, Canada.

Order Halichondrida Gray, 1867

Family Halichondriidae Gray, 1867

9. *Hymeniacidon sinapium* de Laubenfels, 1930

Previous records. Sim, 1982; Sim and Beyon, 1989; Sim and Bae, 1987; Sim and Kim, 1988; Sim and Shim, 2006.

Material examined. Paradise Cove, 9 Feb. 2006; Palos Verdes Peninsula, 12 Oct. 2005; 13 Feb. 2006; Little Corona Del, Mar., 14 Feb. 2006; South End of Crescent Bay, 1

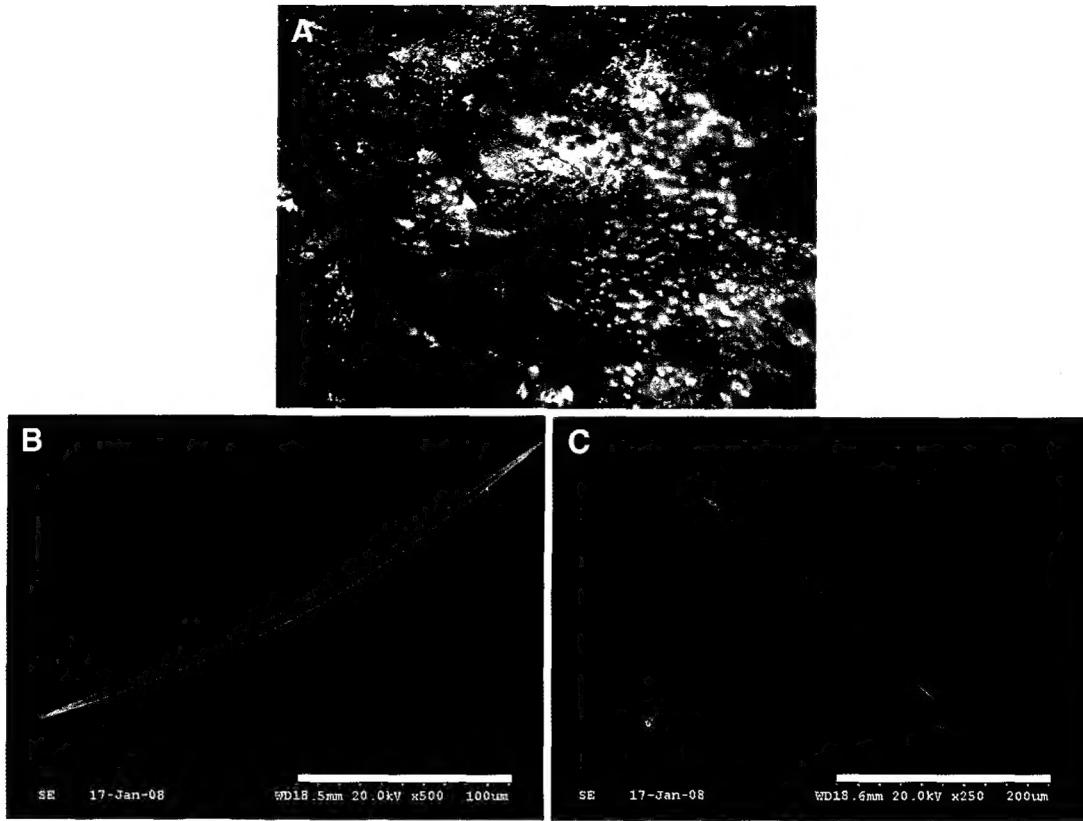


Fig. 11. *Halichondria panicea*. A, entire animal; B, thick oxea; C, thin oxea. Scale bars=100 μm (B), 200 μm (C).

Mar. 2006; Cayucos, 24 Mar. 2006.

Description. Encrusting and massive shape, size up to $1.5 \times 0.8 \times 0.3$ cm. Texture, soft. Colour, yellow in life which gradually changes to ivory. Oscules, 0.1 cm on surface. Spicules, two sizes of style.

Megascleres

Large style $230-305 \times 7-11 \mu\text{m}$

Small style $130-150 \times 3-7 \mu\text{m}$

Remark. The specimen from Korea seems to be close to that from Southern California based on its spicules. Only the small style differs in size. The specimen from Korea has a longer small style (Table 3).

Distribution. Korea, Japan, Southern California.

10. *Halichondria panicea* (Pallas, 1766) (Fig. 11)

Previous records. Sim, 1982; Rho and Yang, 1983; Sim and Bae, 1987; Sim and Beyon, 1989.

Material examined. Cayucos, 24 Mar. 2006; San Simeon, 25 Mar. 2006.

Description. Encrusting shape, size up to $4 \times 4.2 \times 0.3$ cm. Texture, rough and soft. Surface, numerous pore and oscular tubes, 0.1 cm. Colour, yellow in life which gradually

changes to ivory in alcohol. Oscules, not conspicuous. Spicules, oxea.

Megascleres

Oxea $165-340 \times 5-10 \mu\text{m}$

Distribution. Southern California, Korea, Japan.

Order Haplosclerida Topsent, 1928

Suborder Haplosclerina Topsent, 1928

Family Chalinidae Gray, 1867

11. *Haliclona* cf. *permolis* Bowerbank, 1866 (Fig. 12)

Isodictya permolis Bowerbank, 1866, p. 278.

Haliclona cf. *permolis* Sim and Bakus, 1986, p. 8.

Material examined. Cayucos, 24 Mar. 2006; San Simeon, 25 Mar. 2006; Bird Rock, 27 Feb. 2006.

Description. Encrusting shape, size up to $3.5 \times 3.5 \times 0.4$ cm. Texture, rough and soft. Surface, numerous pores and oscular tubes, 0.2-0.3 cm in height. Colour, ivory in alcohol. Oscules, 0.1-0.2 cm. Spicules, megascleres, two sizes of oxea.

Megascleres

Oxea $80-100 \times 5-10 \mu\text{m}$

Slender oxea $70-80 \times 3-4 \mu\text{m}$

Remark. This species from Korea seems to be close to the

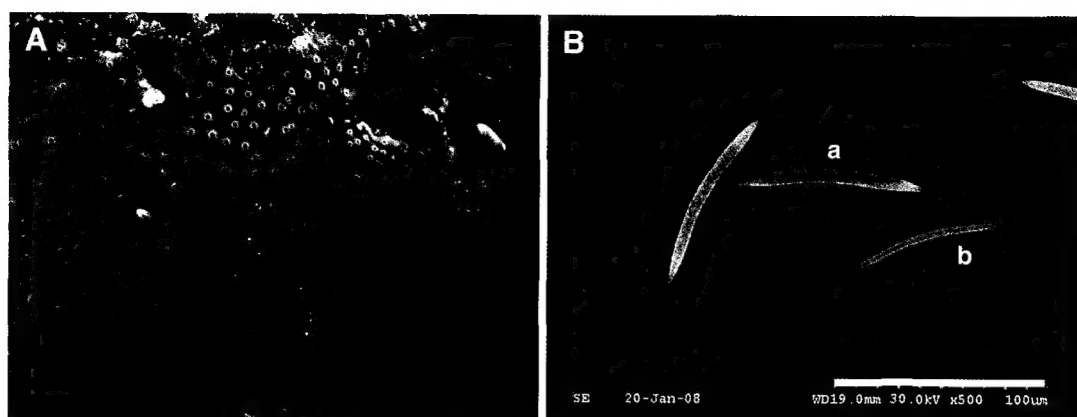


Fig. 12. *Haliclona* cf. *permollis* from California. A, entire animal; B, Megascleres (a, oxea; b, slender oxea). Scale bar=100 μ m (B).

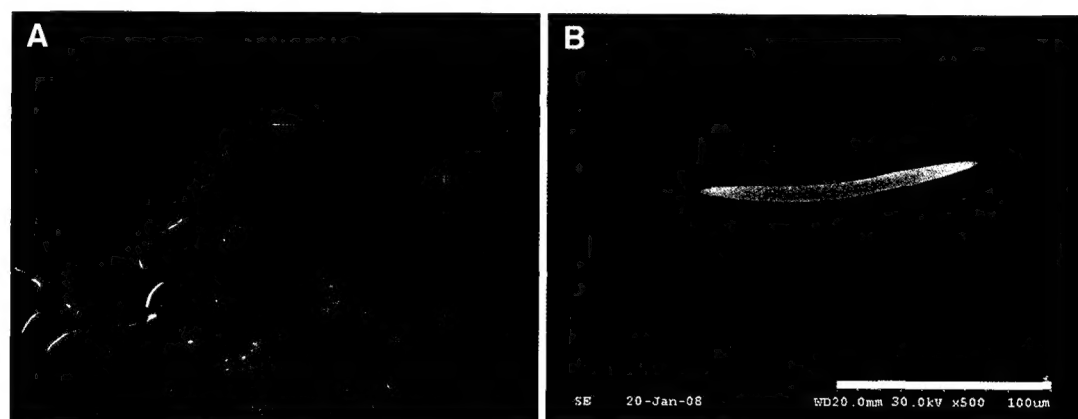


Fig. 13. *Haliclona permollis* (Korea). A, entire animal; B, oxea. Scale bar=100 μ m (B).

Table 4. Comparison between characters of *Haliclona* cf. *permollis* from California and *Haliclona permollis* from Korea

Species (Locality)	Character	Shape	Color	Texture	Spicule (μ m)	
					Oxea	Slender Oxea
<i>Haliclona</i> cf. <i>permollis</i> (Cayucos, Southern California)	Encrusting	—	Soft		80-100 \times 5-10	70-80 \times 3-4
<i>Haliclona</i> cf. <i>permollis</i> (San Simeon, Southern California)	Encrusting	Purple	Soft		65-80 \times 7.5-8	70-75 \times 2.5-3
<i>Haliclona permollis</i> (JeJudo Island, KOREA)	Encrusting	Purple	Soft		125-140 \times 7-8	80-110 \times 2.5

species from Southern California based on its spicules. However, the oxea and slender oxea have a larger diameter range compared to the species from Southern California (Table 4; Figs. 12, 13).

Distribution. Southern California.

Order Dendroceratida Minchin, 1900

Family Darwinellidae Merezkowsky, 1879

12. *Aplysilla glacialis* Merezkowsky, 1878

Simplicella glacialis Merezkowsky, 1878, p. 259.

Aplysilla glacialis: Lendenfeld, 1889, p. 706; de Laubenfelds, 1932, p. 125, fig. 78.

Material examined. Bird Rock, 27 Feb. 2006; Cayucos, 24

Table 5. Comparison of occurred species between Southern California and Korea

Species	Korea	California
<i>Timea authia</i>	x	o
<i>Tethya simi</i>	o	x
<i>Cliona celata</i>	o	o
<i>Strongylocidon conulosa</i>	o	x
<i>Antho (Acarina) karykina</i>	x	o
<i>Antho (Acarina) lithophoenix</i>	x	o
<i>Clathria (Microciona) pennata californiana</i>	x	o
<i>Clathria (Thalysias) originalis</i>	x	o
<i>Acanus erithacus</i>	x	o
<i>Lissodendoryx firma</i>	o	o
<i>Lissodendoryx isodictyalis</i>	o	x
<i>Tedania brevispiculata</i>	o	x
<i>Tedania ignis</i>	o	x
<i>Haliclona permolis</i>	o	x
<i>Haliclona cf. permolis</i>	x	o
<i>Hymeniacidon sinapium</i>	o	o
<i>Hymeniacidon flavia</i>	o	x
<i>Halichondria panicea</i>	o	o
<i>Halichondria okadai</i>	o	x
<i>Aplysilla glacialis</i>	x	o
<i>Aplysina fistularis</i>	x	o
Occurred species	12	13

Mar. 2006.

Distribution. Southern California.

Order Verongida Bergquist, 1978

Family Aplysinidae Carter, 1875

13. *Aplysina fistularis* Pallas, 1766

Spongia fistularis (Pallas, 1766) p. 385.

Verongia aurea de Laubenfels, 1948, p. 84.

Aplysina fistularis Wiedendmyer, 1977, p. 64, pl. 5, fig. 3.

Material examined. Bird Rock, 27 Feb. 2006; South End of Crescent Bay, 1 Mar. 2006.

Distribution. Southern California.

DISCUSSION

This study represents a comparison of intertidal Porifera between California and Korea. The sponge survey ranged from the central California Monterey Peninsula to San Diego. The material examined was collected from 11 localities and is housed in the invertebrate collections of the Los Angeles County Museum of Natural History in Los Angeles. The results of the survey indicate species reduction in polluted areas, but a high diversity in state parks. Our study reported 13 species, nine families, seven orders, and one class of sponges in Southern California. This study has produced 9 species, six families, four orders, and one class in

central California; two species, two families, two orders, and one class in Los Angeles County; three species, three families, three orders, and one classes in Orange County; and four species, four families, four orders, and one class in San Diego County. In the intertidal zone of Korea, 11 species have been reported in Jejudo Island and 6 species in Chujado Island. Common species in Korea and California coastal areas are; *Cliona celata*, *Lissodendoryx firma*, *Halichondria panicea*, *Hymeniacidon sinapium* (Table 5). So far, 9 species from Korea and 5 species (*Echinoclathria* sp., *Clathria* sp., *Ophlitaspongia* sp., *Aplysilla* sp. and *Haliclona* sp.) from California seem new, and we need to for further study.

Recent marine biodiversity is being affected by environmental pollution and climate change. A rich diversity of marine sponges occur at the Monterey Peninsula in central California, which is protected as a marine preservation. The poor diversity of sponges in Los Angeles County is probably due to sewage pollution and land runoff of oil and chemicals via storm drains.

ACKNOWLEDGEMENTS

This work was supported by the Korea Research Foundation Grant funded by the Korean Government (MOEHRD, Basic Research Promotion Fund) (KRF-2005-013-C00038).

We thank Larry Lovell from the Scripps Institution of Oceanography, University of California, San Diego; Vansyoc Bob from the Department of Invertebrate Zoology and Geology, California Academy of Science; Kathy Omura from the Marine Biodiversity processing center, Natural History Museum of L.A. County for providing the sponge collection and recorded field data.

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Received February 11, 2008
Accepted March 6, 2008